OPAL·RT

DRIVELAB KIT
USER MANUAL

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SYMBOL DEFINITIONS

The following table lists the symbols used in this document to denote certain conditions:

Symbol	Definition
	ATTENTION: Identifies information that requires special consideration
	TIP: Identifies advice or hints for the user, often in terms of performing a task
	REFERENCE _ INTERNAL: Identifies an additional source of information within the bookset.
CAUTION	Indicates a situation which, if not avoided, may result in equipment or work (data) on the system being damaged or lost, or may result in the inability to properly operate the process.
	Indicates a situation where users must observe precautions for handling electrostatic sensitive devices.
	CAUTION: Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.
	WARNING: Indicates a potentially hazardous situation which, if not avoided, could result in serious injury or death.

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OVERVIEW

Opal-RT DriveLab kit is a fully integrated motor drive kit, designed to enable the user to perform a variety of experiments on AC and DC machines. The system was specifically designed for teaching, experimentation and research. The system consists of four major components: motors, power electronics, control hardware and control software. The purpose of this document is to provide information, instructions and details about those components.

DRIVELAB KIT CONTENTS

- 1 Real-time simulator (target computer)
- 1 TestDrive pack (model) with user interface
- 4 motors:
  - 1 PM-DC (DC motor, see ”DC Motor” on page 17)
  - 1 PM-DC Gen (DC generator with encoder, see “Dc Generator” on page 18)
  - 1 BLDC (BLDC motor with encoder, see “BLDC Motor” on page 19)
  - 1 Async (AC Induction motor with encoder, see “AC Induction Motor” on page 20)
- 1 DriveLab box
- 1 External DC power supply
- 2 I/O cables (one for digital control signals and one for analog input signals)
- 2 Encoder cables (5-pin and 8-pin)
- 8 Banana plug cables (3 for inverter #1, 3 for inverter #2 and 2 for external power supply)
- Other interface cables (power cord, ethernet cable, etc)

HOW THE KIT WORKS

The DriveLab kit consists of two electric motors fixed on a base plate. Since the motors can be physically coupled, this document assumes that one of the motors is used as a motor and that the other is used as a generator (load of the motor).

Each motor is driven by a separate power converter connected to a common 36 VDC bus. This DC bus is powered by an external power supply (provided with the kit). The power converters have all the drivers and circuit accessories needed to be controlled by PWM logical signals. Current, voltage and mechanical angle/speed sensors give the required feedback to the real-time control prototyping system.

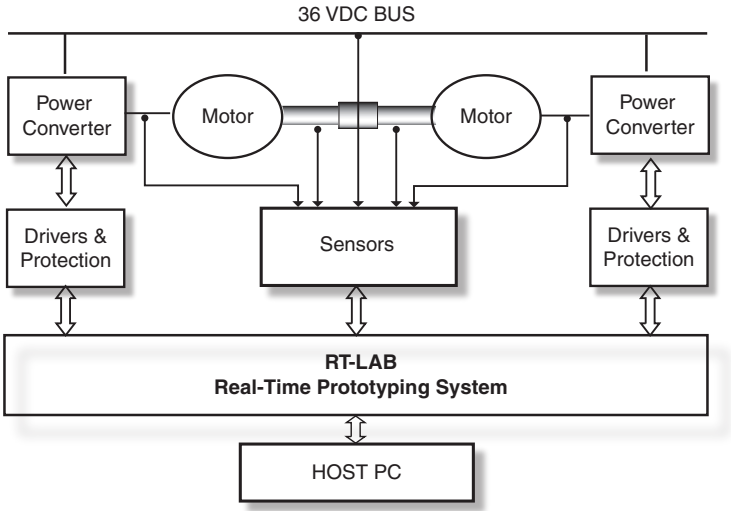


Figure 1: DriveLab solution block diagram

The image (Figure 2) shows the four major DriveLab kit components (motors, power electronics, control hardware (real-time simulator) and control software in relation to the function diagram.

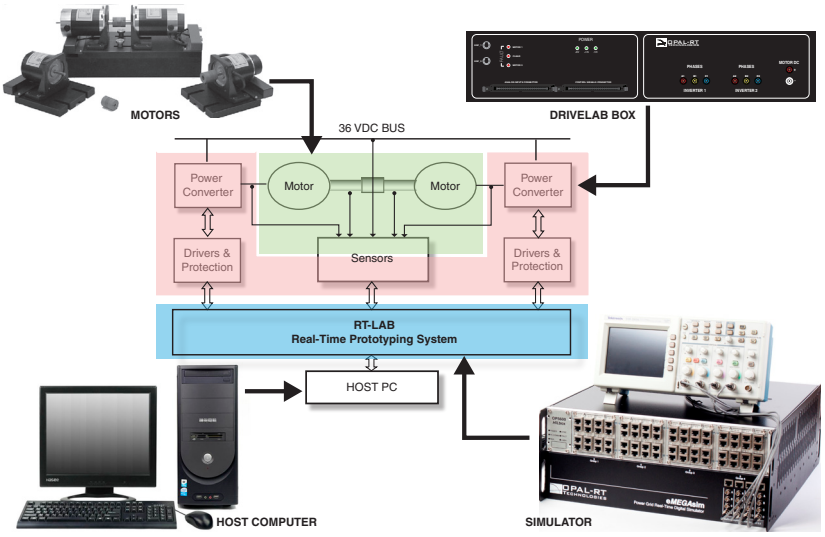


Figure 2: DriveLab solution schematic with components

HOW THE DRIVELAB BOX WORKS

The DriveLab box is a motor drive system in which the PWM pulses generated by the real-time simulator dictate the modulation of a voltage-source converter, and then control the motor. It consists of two identical, independent 3-phase PWM inverter circuits, each one with 3 MOSFETs that allow driving two motors simultaneously. Both circuits provide current feedback for the first two phases (A & B). A 36 VDC-bus voltage is provided to reduce electrical hazards. Feedback of this bus voltage level is also provided. The DriveLab box passes the encoder feedback to the real-time simulator. The box also provides fault detection and clearance.

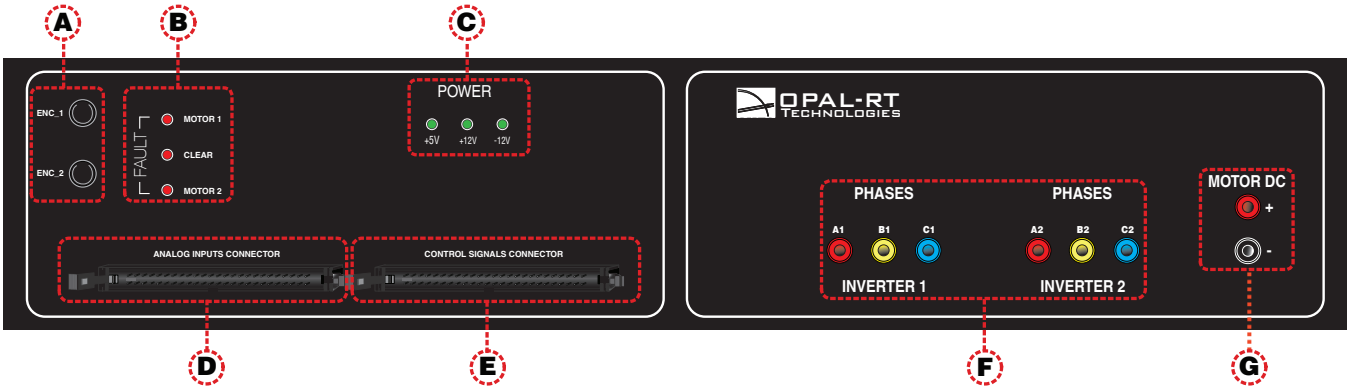


Figure 3: The DriveLab box interface

A. Encoder connectors.
Enc_1 is an 8-pin connector and Enc_2 is a 5-pin connector. See the “Motors” on page 16 section for details.

B. Fault
LEDs for each motor and a clear button (see “fault detection and fault clearance” on page 10).

Label	Display
Motor 1	A fault on motor #1 (via inverter circuit #1)
Motor 2	A fault on motor #2 (via inverter circuit #2)

C. Power
Indicator LEDs display power status for the various power supplies. If all LEDs are off, some functions may not work.

Label	Display
+5V	The DriveLab box is properly powered with +5V
+12V	The DriveLab box is properly powered with +12V
-12V	The DriveLab box is properly powered with -12V

D. Analog inputs connector
Connects DriveLab box to simulator analog inputs.

E. Control signals connector
Connects DriveLab box to simulator digital signals (encoders, hall effects, clear fault, and gate firing for all 3 phases for each inverter).

F. Phases
Voltage output from the three phases (A, B and C) of inverter 1 and 2

G. Power connector
36V external power supply connector to power the board’s DC bus.

POWER ELECTRONICS

The DriveLab box circuit board manages inputs and outputs (see schematic in Figure 4) using MOSFET switching devices, converters, inverters and sensors, among numerous other components. These components are linked to interfaces provided on the DriveLab box (see Figure 3 for details). Each interface provides a connection to another component, such as a host computer, simulator or motors.

The PCB housed within the DriveLab box also offers additional connector components and switches and should only be accessed by qualified technicians and, in certain cases, advanced users. Additional details are provided in “Appendix B” on page 43.

FAULT DETECTION AND FAULT CLEARANCE

The DriveLab box is physically protected against overcurrents. When an overcurrent occurs, it generates a fault, which is indicated in two ways:

1. The front LED lights indicate a fault status (Motor 1 or Motor 2, depending on which inverter is in fault) status of the front associated to that inverter circuit. If the LED is on, it means a fault has occurred on this inverter. The protection ensures the circuit is not damaged and will stop any activity on that circuit.
2. The real-time model also offers the fault detection option using a digital input line. When a fault occurs, the input status changes from 0 (normal operation) to 1 in the real-time model.

The DriveLab box lets users clear the fault using one of two options and continue with the activity:

1. Press the “Clear” button on the front of the DriveLab box to clear the fault.

Note: the Clear function is applied to both circuits, clearing the fault on circuit #1 and on circuit #2. If the fault is properly cleared, the LED that indicated a fault should go off.

2. The real-time model also provides a fault clearance option, which will change the status of a digital signal (from low to high). This signal, sent from the real-time simulator to the DriveLab box, has the same effect as pushing the “Clear” button on the box. After clearing the fault, the fault trigger should be returned to its initial position to ensure the “clear fault” signal does not stay on indefinitely. The fault LED will turn off.

Here is a simplified schematic to illustrate how the board (within the DriveLab box) channels signals:

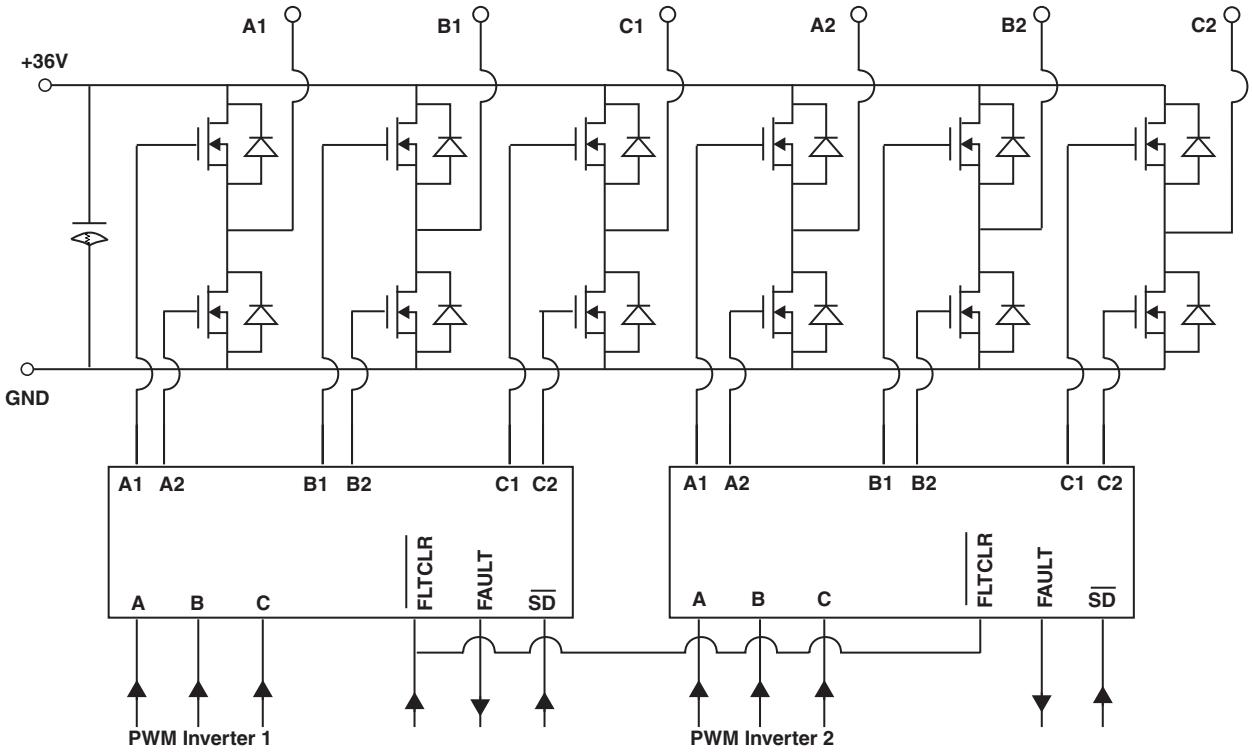


Figure 4: The DriveLab inverter circuits schematic

GETTING STARTED

HOW TO CONNECT THE DRIVELAB BOX

The DriveLab box has thirteen (13) connectors, one in the back and twelve in the front.

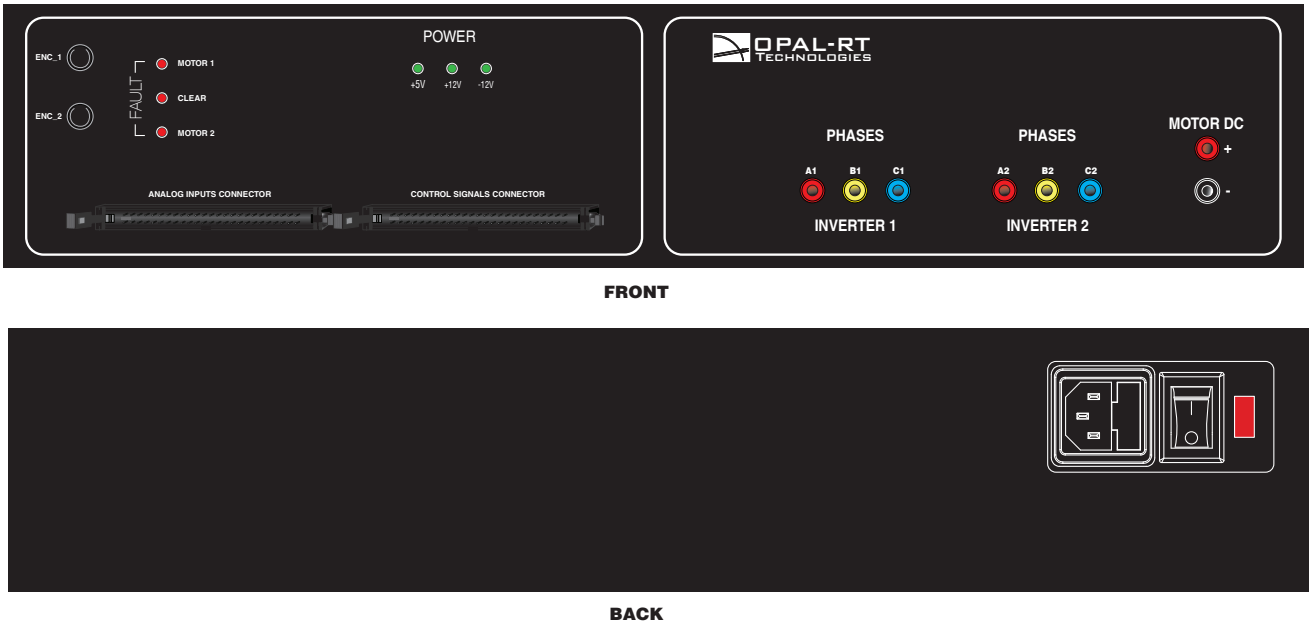


Figure 5: DriveLab box connectors

Location	Label	Type	Used for
Back	N/A	Power cord	Standard 120VAC power cord
Front	ENC_1	Encoder 8 pins	Encoder cable (8-pin type)
	ENC_2	Encoder 5 pins	Encoder cable (5-pin type)
	MOTOR DC +	Banana plug	External power supply +36V
	MOTOR DC -	Banana plug	External power supply ground
	Control signals	40-pin	Control signals (digital) and feedback from/to simulator
	Analog Inputs	50-pin	Feedback returned to simulator through analog signals
	Phase A1	Banana plug	Controlling phase A of motor on inverter circuit #1
	Phase B1	Banana plug	Controlling phase B of motor on inverter circuit #1
	Phase C1	Banana plug	Controlling phase C of motor on inverter circuit #1
	Phase A2	Banana plug	Controlling phase A of motor on inverter circuit #2
	Phase B2	Banana plug	Controlling phase B of motor on inverter circuit #2
	Phase C2	Banana plug	Controlling phase C of motor on inverter circuit #2

Table 1: DriveLab box connectors

CABLING

Before turning the DriveLab box on, make sure all connections are secured (power cord, encoder cables, external power supply cables, motor cables and I/O cables):

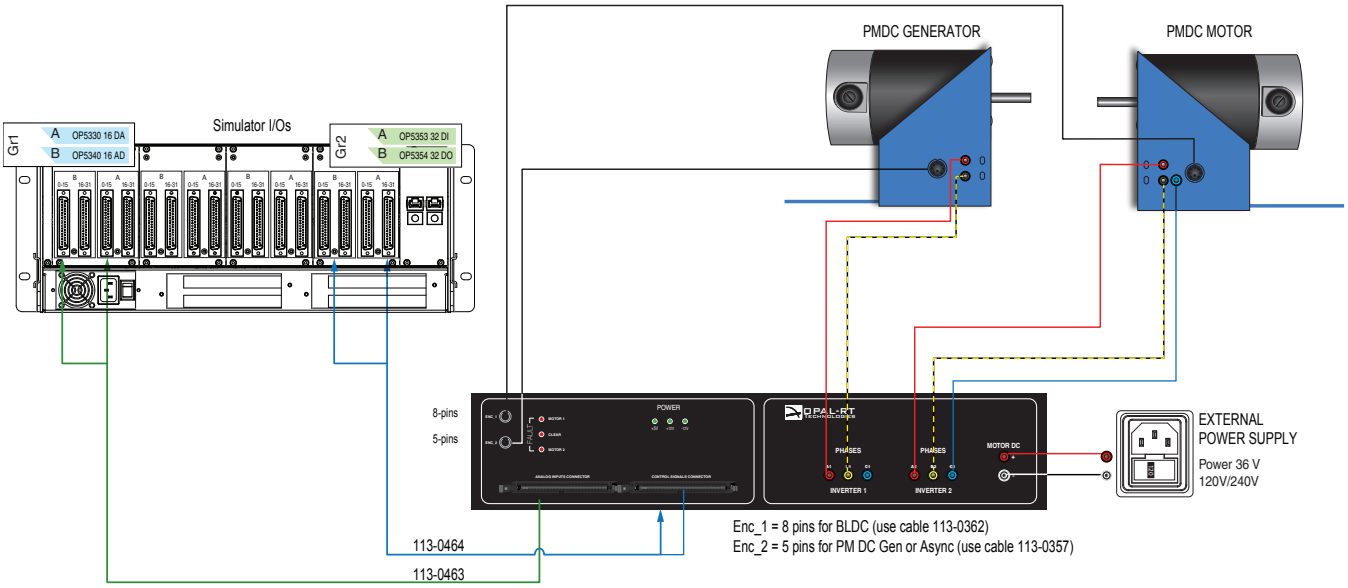


Figure 6: Complete cabling diagram

1. Make sure that the DriveLab box, real-time target and external power supply are off.
1. Connect the I/Os from the DriveLab box to the simulator using cables 113-0463 and 113-0464.
2. Connect the desired motor (PMDC in the illustration) to the DriveLab box banana jacks using the cables provided, making sure to respect color coding. (shown in Figure 6
3. Connect the DriveLab encoder to the motor using either cable 113-0357 (5-pin connector) or 113-0362 (8-pin connector).
4. Connect the external power supply (make sure that it is OFF and that the voltage control is set to 0) to the banana jacks on the front of the DriveLab box.
5. Connect the standard power cord to the DriveLab box and plug into an adequate wall plug.

POWERING UP SEQUENCE

Before connecting any power supply to the DriveLab box, make certain that the external power supply voltage setting is set to a maximum of 36 VDC (see “Appendix C” on page 48**).**

1. Put DriveLab power switch (at the back of the unit) in the ON position. The three (3) LEDs in the front (+5V, +12V and -12V) will light.
2. Make sure that the external power supply voltage is set to 0. Turn on the power supply.
3. Turn on real-time target (simulator).
4. Slowly increase the voltage until you reach 36V.

Note: Upon powering up the DriveLab box, there may be some noise caused by the lower voltages. This noise will disappear once the unit reaches its nominal voltage setting. This same noise may also occur due to lowering voltages during the powering off sequence.

CONTROL HARDWARE

The control hardware is comprised of Opal-RT engineered components and some standard computer components (such as Intel processors) to achieve very high-speed and precision real-time simulation. The DriveLab kit includes the external power supply, the interface cables and the real-time simulator. The real-time simulator components can be divided into two categories: PC-based and Inputs/Outputs (I/Os). A motherboard, hard drive with RTOS, power supply and processors are the main components of the PC-based category. An FPGA board based on Spartan-3 Xilinx's chip with PCI Express interface, digital I/O boards and +/-16V analog board are the main components of the I/O category. For the DriveLab kit application, we will focus on the I/O interface.

REAL-TIME SIMULATOR I/O

ANALOG INPUTS

Opal-RT's standard analog input range is +/-20V. The DriveLab application scales the voltages in order to comply with this specification. The analog input carrier connector on the real-time simulator is known as a DB37F connector (see "I/O Cables" on page 15 for details).

In this configuration, analog inputs are used to read the phase currents and the DC bus voltage.

- Currents A1 and B1 of inverter circuit #1
- Currents A2 and B2 of inverter circuit #2
- +36V common DC bus voltage

Note that currents are measured and sent as voltages by the DriveLab box (see "Power electronics" section for more details). A gain is applied during the conversion. See "Control software" section on how to retrieve the exact current values in the model.

DIGITAL INPUTS

Opal-RT digital inputs are opto-isolated.

In this configuration, digital inputs are used to read encoder feedback provided by the DriveLab box and the encoders:

- Fault detection on inverter circuit #1
- Fault detection on inverter circuit #2
- Encoder feedback (A, B, Z) from both encoders
- Hall effects (U1, V1, W1) of encoder 1 (8-pin)

Opal-RT digital outputs are opto-isolated and require an external DC voltage source as a voltage reference level for the digital signals to be outputted. In the DriveLab application, this voltage is fed by the DriveLab box to the real-time simulator.

In this configuration, digital outputs are used to provide signals to the DriveLab box:

- Firing of phase A1, B1 & C1 (PWMs) on inverter circuit #1
- Firing of phase A2, B2 & C2 (PWMs) on inverter circuit #2
- Fault clearance signal (common to both circuits)

I/O CABLES

Real-time simulator inputs and outputs must be properly connected to the DriveLab box to interact with it. This is why Opal-RT provides two custom cables to connect both systems; each cable has two different connectors at either end:

113-0371 ANALOG INPUT CABLE

- Standard DB37M connector (to connect to the simulator analog I/O slot).
- 50-pin connector (to connect to the DriveLab box “analog inputs” connector).

Refer to “pin assignments” on page 29 for the analog input DB37 pin description and for the 50-pin “analog inputs” connector pin description.

113-0372 DIGITAL I/O CABLE

- Standard DB37M connector (to connect to the simulator digital I/O slot).
- 40-pin connector (to connect to the DriveLab box “control signals” connector).

Refer to “pin assignments” for the digital I/O DB37 pin description and for the 40-pin “control signals” connector pin description.

CAUTION The “analog input” and the “control signal” connectors on the DriveLab box are different sizes, therefore, there is no risk of plugging in the wrong connector.

However, the connectors on the simulator are the same size, therefore it is IMPERATIVE to plug the “analog input” cable into the analog input slot and the “control signal” cable into the digital I/O slots.

Failure to do so may result in hardware damage of the DriveLab box, the cable and the real-time simulator. If you are not sure, refer to the System Integration documentation found on the CD provided with the system or refer to your project manager.

EXTERNAL POWER SUPPLY

The external power supply provided with the system is used to power the DriveLab box, which requires an external +36VDC source to power the common DC bus. Although the power supply provided may be able to reach higher voltages, it must be set to +36VDC. Higher voltages may result in damage to the DriveLab box and to other hardware components.

Before connecting the external power supply to the DriveLab box, set the power supply to 0V. Then, connect the external power supply to the DriveLab box and power them. It is important to power the DriveLab box and the external power supply after both units are connected together.

MOTORS

The DriveLab kit includes four different motor types: DC, AC induction, BLDC and DC generator. Motors can be coupled (as shown) or left separate. The image below shows a typical configuration.

Motors are connected to other devices using various types of cables: banana jack cables, custom 40 or 50 pin to DB37 or round 5 or 8 pin encoder cables.

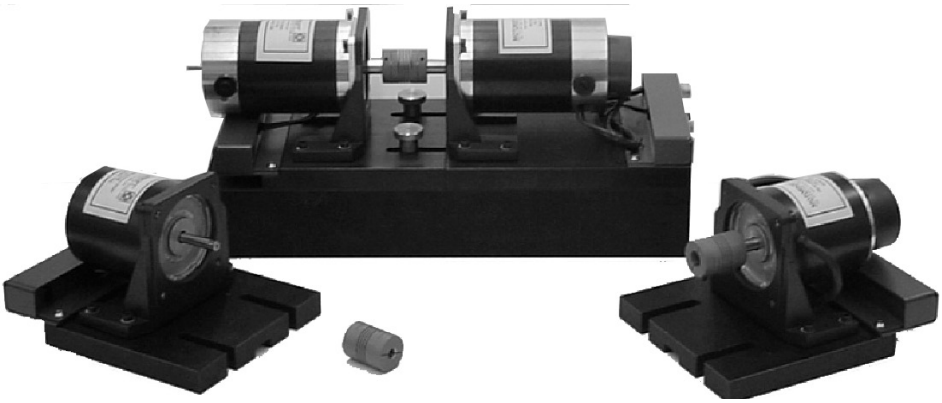


Figure 7: The DriveLab motors

Note: Only the BLDC motor uses the 8-pin encoder (pins 6, 7, and 8). The DC generator and the AC Induction motor both use the 5-pin encoder. Therefore, if the DC generator and the AC Induction motor are used in the same experiment, it is possible to monitor only one encoder. The encoders' resolution is 1000 pulses per revolution.

DC MOTOR

The DriveLab kit is equipped with a third party (COTS) DC motor that can be connected to the DriveLab box. You must follow the connection instructions provided in Table 2 to connect this motor to the DriveLab box inverter connectors.

CONNECTIONS

The DC motor has two (2) connectors: Phase 1 (red) on the DriveLab box must be connected to the red connector on the DC motor. Phase 2 (yellow) on the DriveLab box must be connected to the black connector on the DC motor.

	DC Motor Connectors			DriveLab box connectors		
Name	**Location**	**Color**	**Type**	**Connector**	**Color**	**Type**
Phase 1	Side	Red	Banana plug	A1 or A2	Red	Banana plug
Phase 2	Side	Black	Banana plug	B1 or B2	Yellow	Banana plug

Table 2: DC motor connectors

Here is an example of connections in which the DC motor is connected to inverter circuit 2.

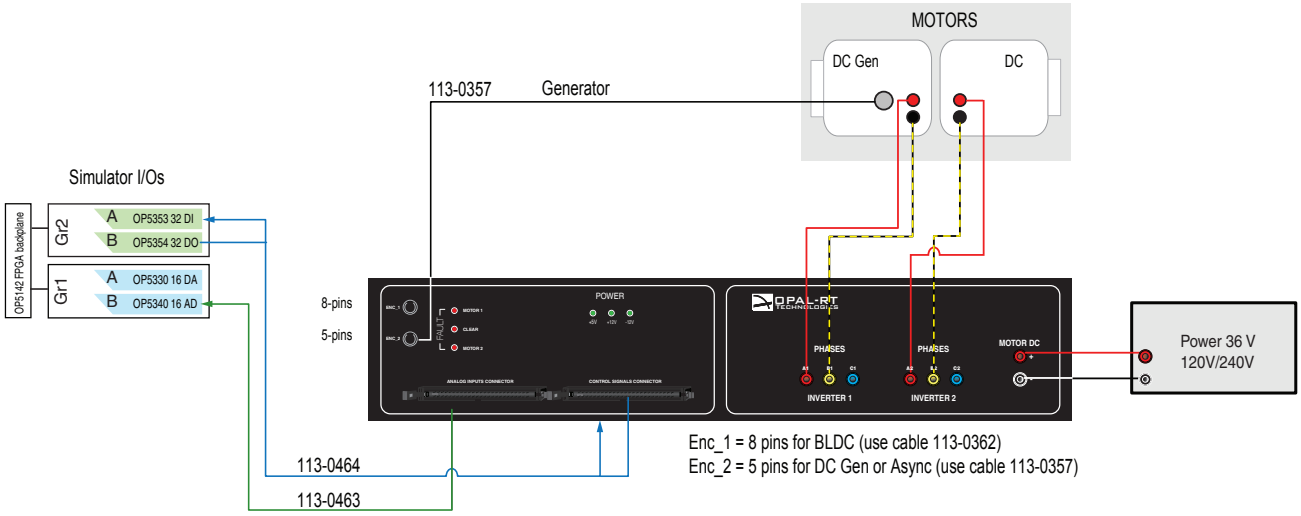


Figure 8: DC motor setup example

MODEL

Opal-RT provides a basic control and feedback open loop model for users who do not have their own DC motor RT-LAB model. The DriveLab RT-LAB Simulink model contains control, I/O interface and feedback subsystems to run the DC motor. The control is a simple DC voltage slider that offers -36V to 36V voltage range with bi-directional control. The model also provides fault clearance control. The I/O interface allows the user to run the DC motor using inverter circuit 1 or inverter circuit 2 depending on the desired application. The feedback returns the currents on phase 1 and phase 2, fault status and the DC bus voltage.

DC GENERATOR

The DriveLab kit is equipped with a third party (COTS) DC generator that can be connected to the DriveLab box. You must follow the connection instructions provided in Table 3 to connect this generator to the DriveLab box inverter connectors.

CONNECTIONS

The DC generator has three (3) connectors: Phase 1 (red) on the DriveLab box must be connected to the red connector on the DC generator. Phase 2 (yellow) on the DriveLab box must be connected to the black connector on the DC generator.

	DC Generator Connectors			DriveLab Box Connectors		
Name	**Location**	**Color**	**Type**	**Connector**	**Color**	**Type**
Phase 1	Side	Red	Banana plug	A1 or A2	Red	Banana plug
Phase 2	Side	Black	Banana plug	B1 or B2	Yellow	Banana plug
Encoder 2	Side	n/a	5 pin	Enc_2	n/a	5 pin

Table 3: DC generator connectors

Here is an example of connections in which the DC generator is connected to inverter circuit 1.

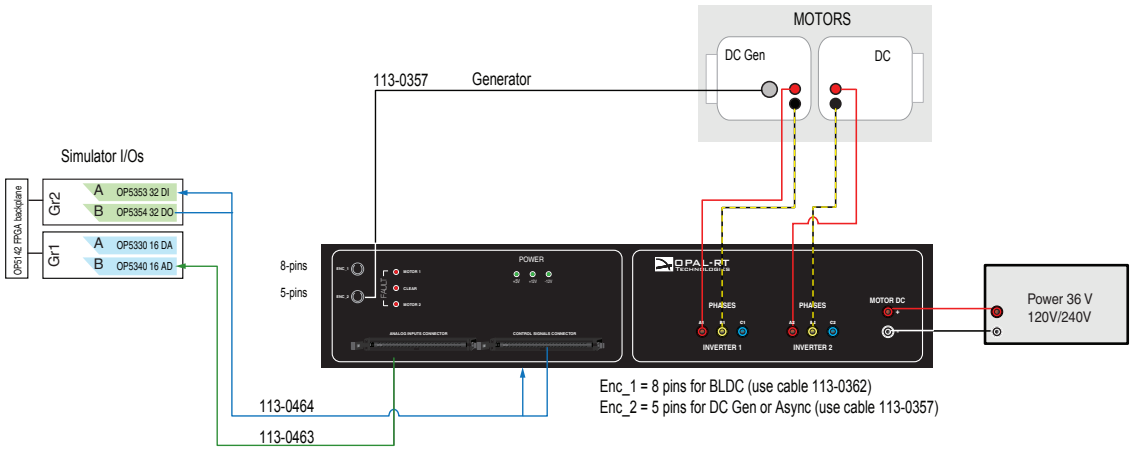


Figure 9: DC generator setup example

MODEL

Opal-RT provides a basic control and feedback open loop model for users who do not have their own DC generator RT-LAB model. The DriveLab RT-LAB Simulink model contains control, I/O interface and feedback subsystems to run the DC generator. The control is a simple DC voltage slider that offers -36V to 36V voltage range, with bi-directional control. The model/subsystem also provides fault clearance control. The I/O interface allows the user to run the DC generator using inverter circuit 1 or inverter circuit 2 depending on the desired application. The feedback returns encoder-based quantities (speed, angle and direction), currents on phase 1 and phase 2, fault status and the DC bus voltage.

BLDC MOTOR

The DriveLab kit is equipped with a third party (COTS) BLDC motor that must be connected to the DriveLab box. You must follow the connection instructions provided in Table 4 to connect this motor to the DriveLab box inverter connectors.

CONNECTIONS

The BLDC motor has four (3) phase connectors: Phase 1 (red) on the DriveLab box must be connected to the red connector on the BLDC motor. Phase 2 (yellow) must be connected to the yellow connector on the BLDC motor and Phase 3 (blue) must be connected to the blue connector of the BLDC motor.

BLDC Motor Connectors				DriveLab box connectors		
Name	**Location**	**Color**	**Type**	**Connector**	**Color**	**Type**
Phase 1	Side	Red	Banana plug	A1 or A2	Red	Banana plug
Phase 2	Side	Yellow	Banana plug	B1 or B2	Yellow	Banana plug
Phase 3	Side	Blue	Banana plug	C1 or C2	Blue	Banana plug
Encoder 1	Side	n/a	8-pin	Enc_1	8-pin	8-pin

Table 4: BLDC connectors

Here is an example of connections in which the BLDC motor is connected to inverter circuit 2.

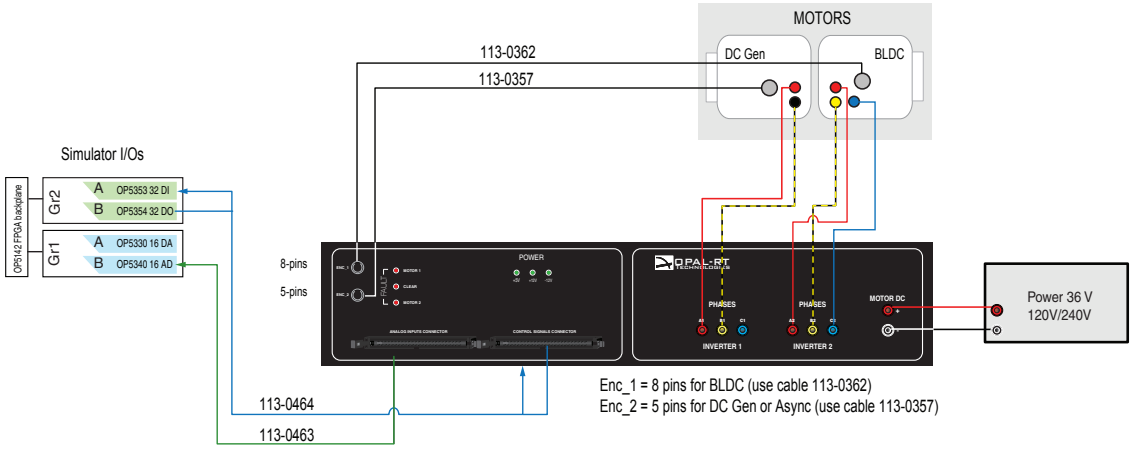


Figure 10: BLDC setup example

MODEL

Opal-RT provides a basic control and feedback open loop model for users who do not have their own DC generator RT-LAB model. The DriveLab RT-LAB Simulink model contains control, I/O interface and feedback subsystems to run the BDLC motor. The control is a simple slider that a 0 - 100% duty range, with a single directional control. The model/subsystem also provides fault clearance control. The I/O interface allows the user to run the BLDC motor using inverter circuit 1 or inverter circuit 2 depending on the desired application. The feedback returns encoder-based quantities (speed, angle and direction), currents on phase 1 and phase 2, fault status, Hall effects (U, V, W) and the DC bus voltage.

AC INDUCTION MOTOR

The DriveLab kit is equipped with a third party (COTS) AC Induction motor that can be connected to the DriveLab box. You must follow the connection instructions provided in Table 3 to connect this AC Induction motor to the DriveLab box inverter connectors.

CONNECTIONS

The DC generator has four (3) phase connectors: Phase 1 (red) on the DriveLab box must be connected to the red connector on the AC Induction motor. Similarly, phase 2 (yellow) must be connected to the yellow connector on the AC Induction motor and phase 3 (blue) must be connected to the blue connector of the AC Induction motor.

	AC Induction Motor Connectors			DriveLab box connectors		
Name	**Location**	**Color**	**Type**	**Connector**	**Color**	**Type**
Phase 1	Side	Red	Banana plug	A1 or A2	Red	Banana plug
Phase 2	Side	Yellow	Banana plug	B1 or B2	Yellow	Banana plug
Phase 3	Side	Blue	Banana plug	C1 or C2	Blue	Banana plug
Encoder 2	Side	n/a	5 pin	Enc_2	n/a	5 pin

Table 5: AC Induction connectors

Here is an example of connections in which the AC Induction motor is connected to inverter circuit 2.

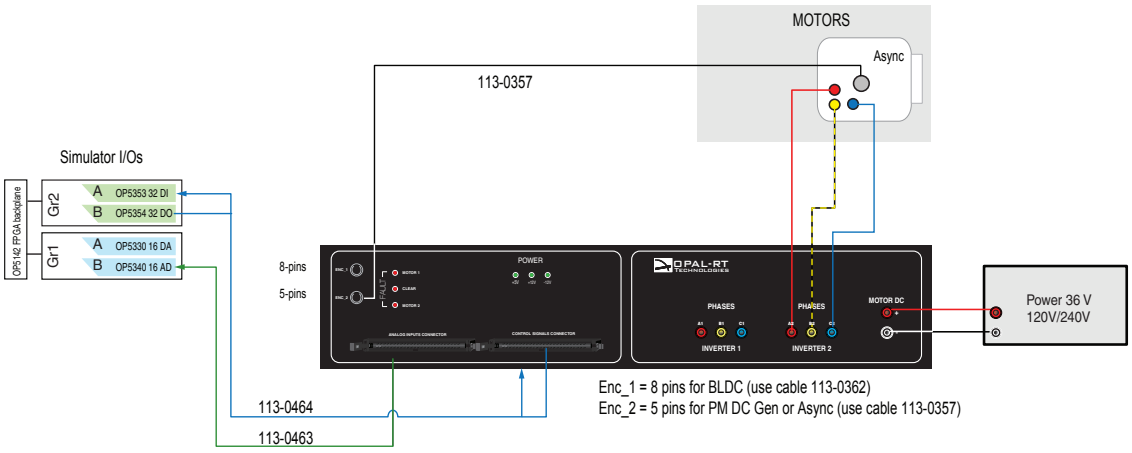


Figure 11: AC Induction setup example

MODEL

Opal-RT provides a basic control and feedback open loop model for users who do not have their own AC Induction RT-LAB model. The DriveLabKit RT-LAB Simulink model contains control, I/O interface and feedback subsystems to run the AC Induction motor. The control is a simple current frequency slider allowing -120Hz to 120Hz frequency range with bi-directional control. The subsystem also provides fault clearance control. The I/O interface allows the user to run the AC Induction motor using the inverter circuit 1 or the inverter circuit 2 depending on the desired application. The feedback returns encoder-based quantities (speed, angle and direction), the currents of phase 1 and phase 2, the fault status and the DC bus voltage.

CONTROL SOFTWARE

HOW THE MODEL WORKS

Opal-RT provides a complete and fully-integrated model and interface for the DriveLab kit. The kit allows users to quickly setup a simulation to perform tests on their choice of motor and inverter circuit.

The model provided already includes all the required I/O access for such classic applications as position control and speed control as shown in Figure 12 and Figure 13

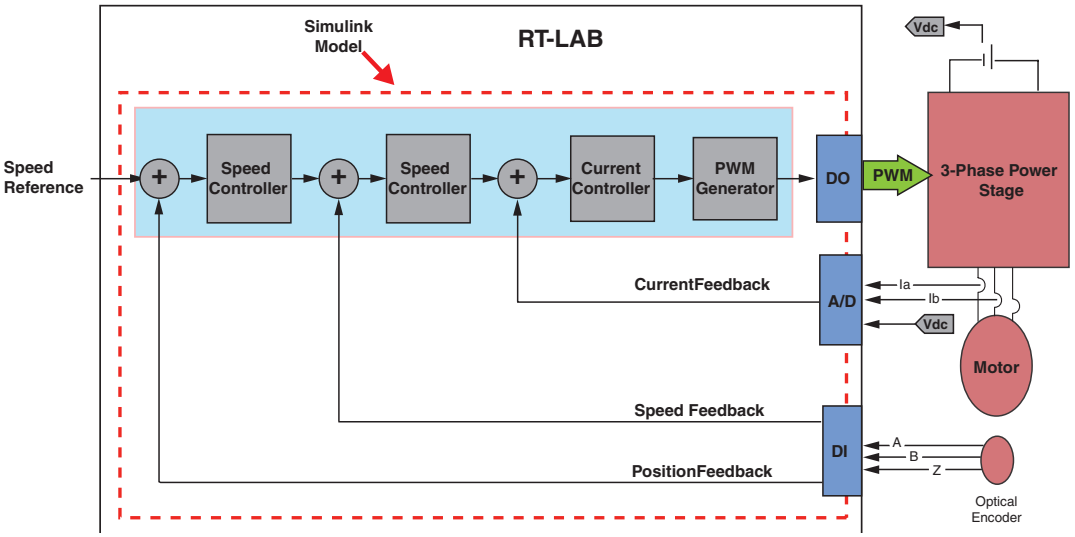


Figure 12: Position control schematic

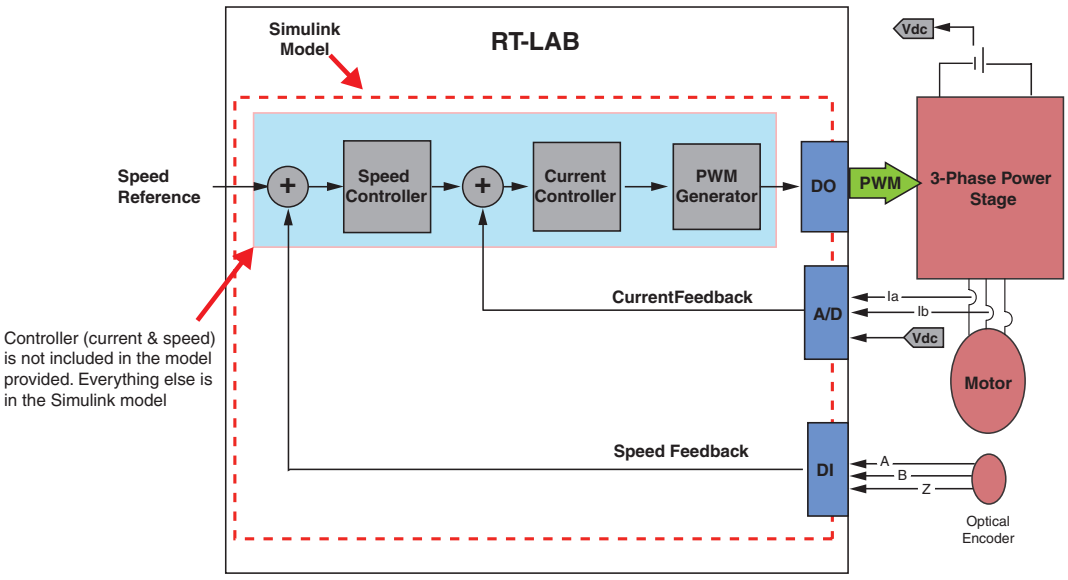


Figure 13: Speed control schematic

Note: Basic knowledge of RT-LAB is sufficient to use the DriveLab kit with its preconfigured models, however, if users wish to modify the models or perform other tests, a more advanced knowledge is required. Refer to the RT-LAB User Guide and to the training material for more details.

THE MODEL

The model provided with the DriveLab kit contains multiple subsystems that users may modify in order to implement their own control and algorithms. The references, controls and feedbacks are easily accessible and can be modified as needed. *The common I/O interface subsystem should only be modified by advanced users*.

The model references are located in the console subsystem (SC) of the RT-LAB model, which includes: frequency, voltage and duty controls that are used as references for the various motors. The reference range and type can be modified to suit different type of controls. Motor selection and clear fault options are also available. Make sure to select which motor is connected to which inverters before using the references controls.

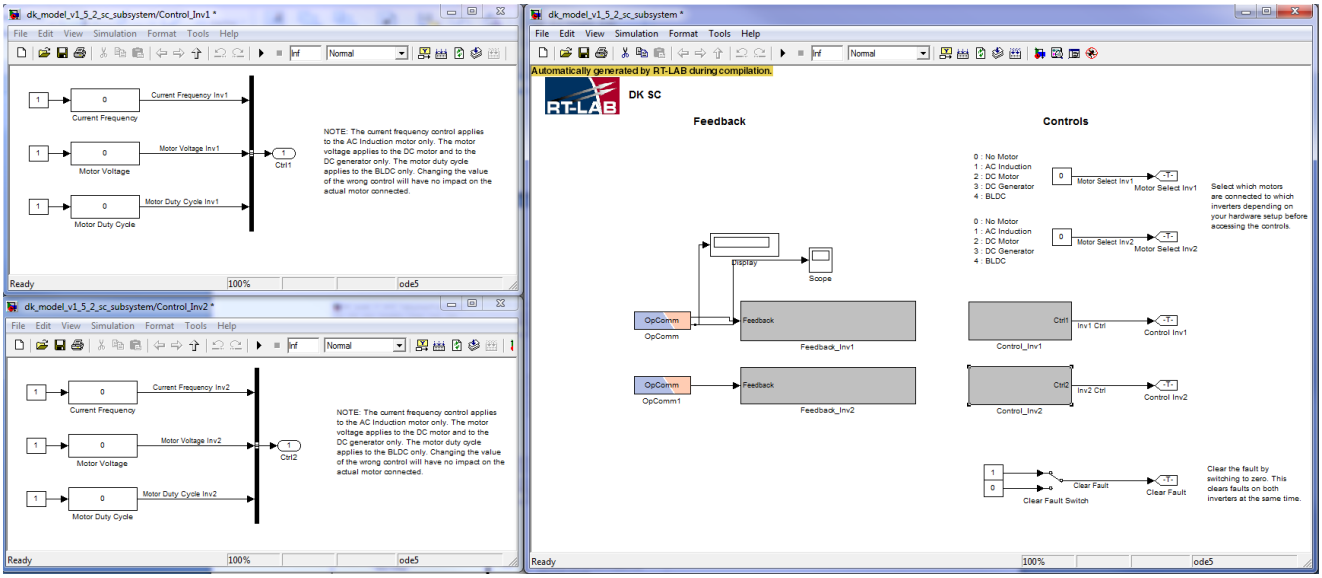

dk_model_v1_5_2_sc_subsystem/Control_Inv1 *
Current Frequency Inv1
Motor Voltage Inv1
Motor Duty Cycle Inv1
Ctrl1
NOTE: The current frequency control applies to the AC Induction motor only. The motor voltage applies to the DC motor and to the DC generator only. The motor duty cycle applies to the BLDC only. Changing the value of the wrong control will have no impact on the actual motor connected.
dk_model_v1_5_2_sc_subsystem/Control_Inv2 *
Current Frequency Inv2
Motor Voltage Inv2
Motor Duty Cycle Inv2
Ctrl2
dk_model_v1_5_2_sc_subsystem *
Automatically generated by RT-LAB during compilation.
DK SC
Feedback
Controls
Display
Scope
OpComm
Feedback
Feedback_Inv1
Feedback_Inv2
Control_Inv1
Control_Inv2
Motor Select Inv1
Motor Select Inv2
Select which motors are connected to which inverters depending on your hardware setup before accessing the controls.
Clear Fault
Clear Fault Switch
Clear the fault by switching to zero. This clears faults on both inverters at the same time.
Ready
100%
ode5

Figure 14: Model References part

The controls model section (circled in red) is found in the master subsystem (SM) of the RT-LAB model. It precedes the common I/O interface because the results of the control are frequency and duty sent to digital outputs (PWM). This is the part of the model in which users can implement their control logic to provide frequency and duty to the PWMO block. The reference is received from the console subsystem, which can be considered the set point. If using speed or position control, feedback must be looped back into this model part.

The model feedback section (circled in green) is also located in the master subsystem (SM) of the RT-LAB model. Note that the final displays and graphical interfaces are found in the console (SC) as per visual requirements but the main routing and logic addition (if needed) will be in the master subsystem. It is connected to the common I/O interface by retrieving the information provided by analog and digital inputs of the real-time simulator. For each motor, a specific feedback routing is implemented to obtain the right values. For example, the BLDC motor's encoder can only be connected to encoder 1 connection of the DriveLab box. Therefore, the routing found in the BLDC feedback subsystem is consequent and returns encoder 1 feedback, regardless of the inverter circuit to which the BLDC is actually connected.

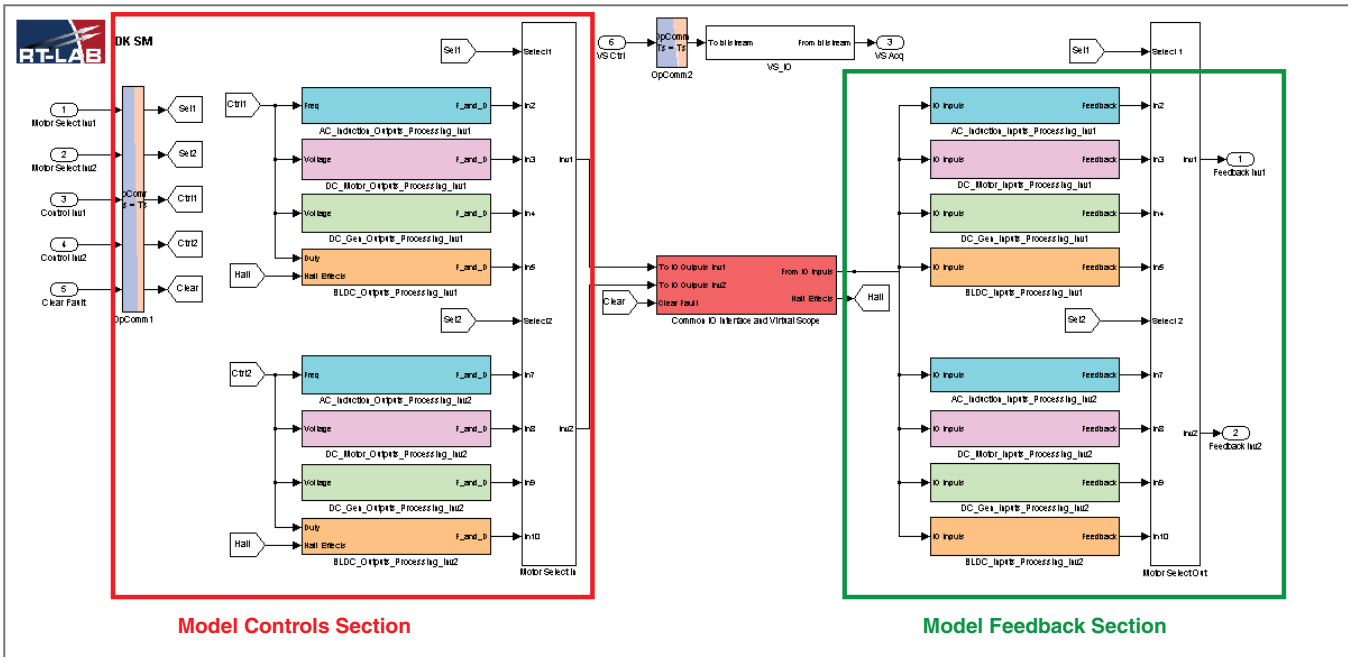


Figure 15: Control and Feedbacks model sections

THE TESTDRIVE INTERFACE

The interface provided with the DriveLab kit uses TestDrive software, Opal-RT Technologies' solution for clean and efficient interfacing. The TestDrive software is based on NI NI LabView panels, on which signals can be assigned to control and display them as needed.

Three editable panels are provided for the DriveLab kit[1]: one for inverter circuit 1, inverter circuit 2 and Virtual Scope. Each panel already has the appropriate signal assignments.

TESTDRIVE WORKBENCH FOR DRIVELAB

The main screen provides several buttons and menus that control interaction with the model.

Figure 16: TestDrive, DriveLab main screen

The left side of the screen offers buttons to control what will be displayed:

DK_Inv1: displays the Inverter 1 page, with Motor Selection menu.

DK_Inv2: displays the Inverter 2 page, with Motor Selection menu.

VirtualScop: displays the Virtual Scope page.

1 Opal-RT packages the model with the NI LabView runtime engines that are necessary to run the Opal-RT TestDrive interface. Therefore, users need not have NI LabView installed.

The Motor Selection option (in center screen) lets users select the type of motor to connect to the inverter. Motor options are:

- No Motor
- AC Induction
- DC Motor
- DC Generator
- BLDC

Once the motor is selected, the screen automatically switches to the panel specific to that motor. AC Induction, DC Generator and BLDC all display the following graphs:

- Speed (RPM)
- Angle (Degrees)
- Current A1
- Current B1
- DC Bus Voltage

The DC Motor panel only displays three graphs:

- Current A1
- Current B1
- DC Bus Voltage

Two controls are available to the right of the panel at all times:

Clear Fault: Click to clear the fault on both inverters. Once pressed, it automatically reverts to its initial position. Refer to “fault detection and fault clearance” for more details about fault clearance.

Click to come back to motor selection: Use this button to return to the main screen and to select another motor on that particular inverter.

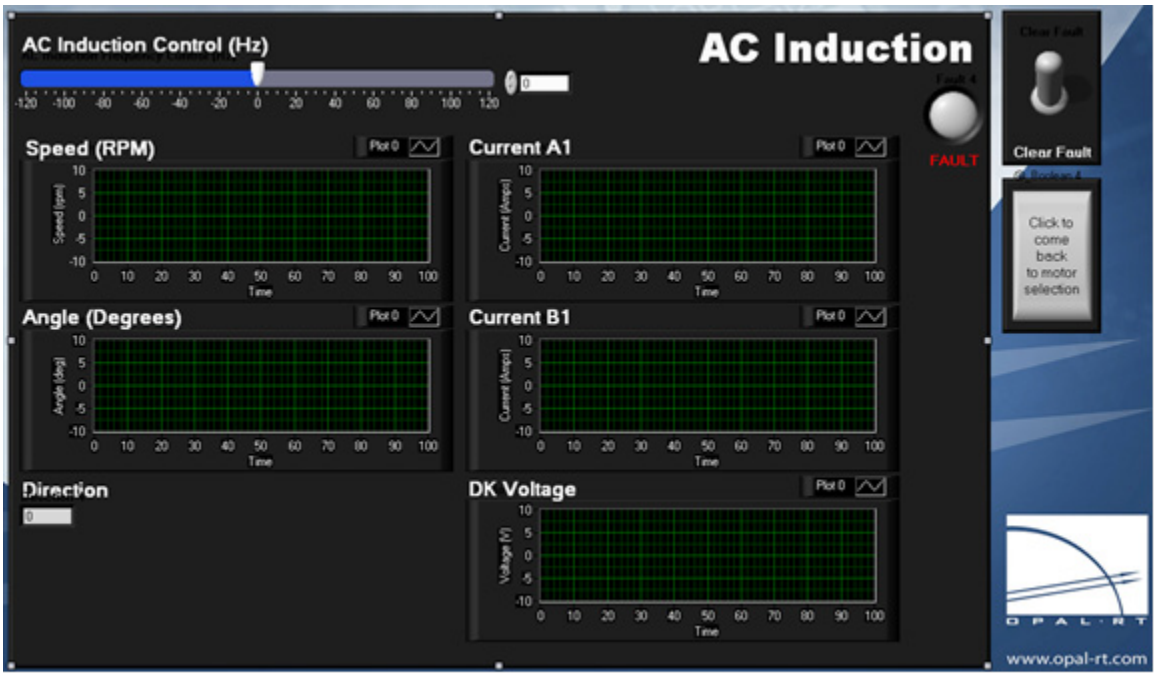


Figure 17: AC Induction page

Virtual Scope Panel

The Virtual Scope panel is included as an add-on for the DriveLab kit. The Virtual Scope samples analog inputs at 2.5 µs and displays the results on graphs. It does not go through standard acquisition process, to which both the Simulink console (SC subsystem) and the TestDrive interface are subject. Therefore, more detailed feedback signals can be visualized. The Virtual Scope displays the five (5) analog signals in the following order:

1. Common 36V DC bus voltage
2. Phase 1A current
3. Phase 1B current
4. Phase 2A current
5. Phase 2B current

Triggering and recording features are available. Please refer to the Virtual Scope's documentation for more information about how to use it (http://www.opal-rt.com/sites/default/files/software/TestDrive%20User%20Manual.pdf).

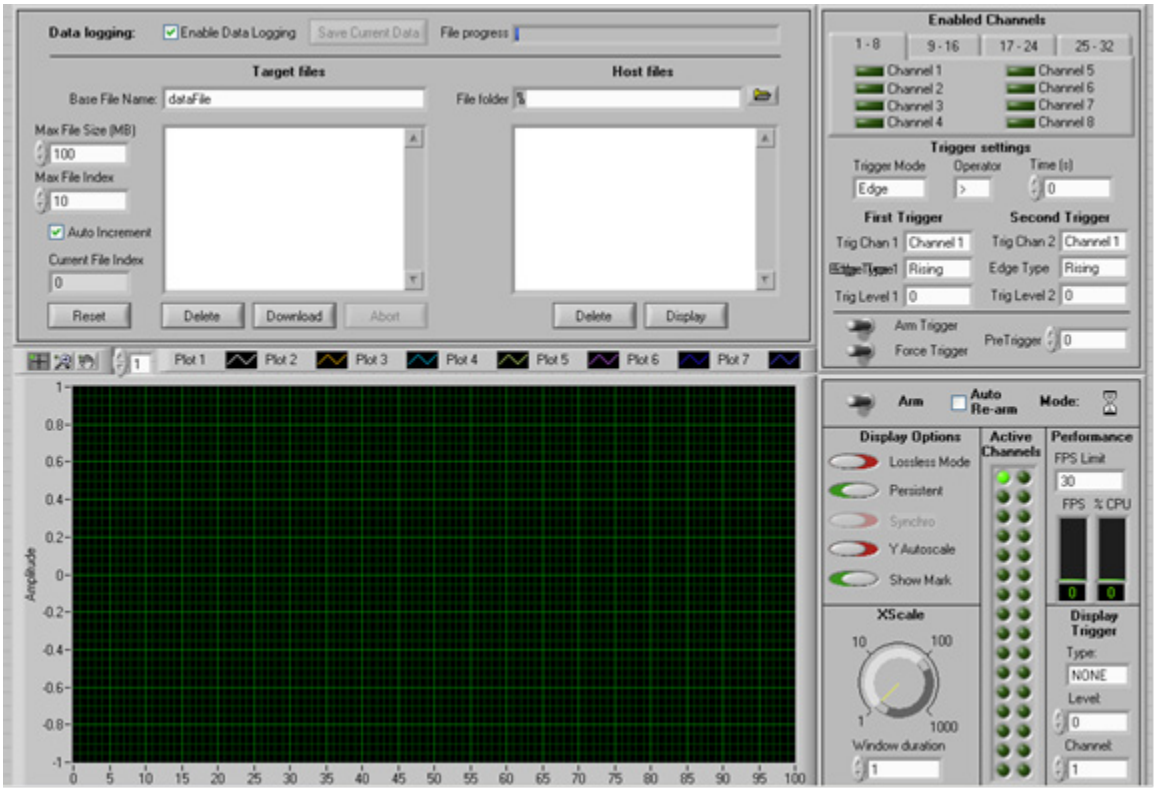


Figure 18: Graphical interface Virtual Scope page

SPECIFICATIONS

DRIVELAB BOX

Product name	DriveLab Connection Box
Part number	429-0001
Power supply	Universal 120/220 standard power connector 36 Vdc external
Connectors	6 banana jack (Phases A1, B1, C1 and A2, B2, C2) 2 encoder (one 5-pin, one 8-pin) 2 banana jack (power) 40-pin analog 50-pin control signals
Dimensions (HxWxD)	8.7 x 43 x 26.7cm (3.43”x 16.93” x 10.51”)
Weight	x.x Kg (x.x lb) – depending on conditioning board configuration
Operating temperature	10 to 40 ºC (50 to 104ºF)
Storage temperature	-55 to 85ºC (-67 to 185ºF)
Relative humidity	10 to 90% non-condensing
Maximum altitude	2000 m (6562 ft.)

DC MOTOR

See “Appendix A - Speed, torque curves” on page 39 for DC motor speed-torque, current-torque and power efficiency-speed curves.

Rated volts	36 VDC
Maximum Speed	4000 RPM
Arm resistance (av. incl. brushes & leads)	0.59 ohm
Ke	7.51 V/KRPM
Kt	0.074 Nm/A
Rated output	250 W
Peak rated output	350 W for 20 seconds
Encoder type	No encoder
Dimensions (HxWxD)	12.5 x 17 x 15cm (4.92”x 6.7” x 6”)
Weight	3.0 Kg (6.61lb)

BLDC MOTOR

Specifications	Value
Rated power	200 W
Rated volts	36 VDC
Maximum Speed	3000 RPM
Ke	9.5 V/KRPM
Resistance (L-L)	0.4 Ohms
Inductance (L-L)	540 µH
Encoder type	8 pins
Dimensions (HxWxD)	12.5 x 17 x 15cm (4.92”x 6.7” x 6”)
Weight	3.0 Kg (6.61lb)

DC GENERATOR

Specifications	Value
Rated power	250 W
Rated volts	36 VDC
Maximum Speed	3000 RPM
Ke	7.51 V/KRPM
No load current	0.97 Amps
Resistance (L-L)	2.9 Ohms
Encoder type	5 pins
Dimensions (HxWxD)	12.5 x 15 x 15cm (4.92”x 6” x 6”)
Weight	3.0 Kg (6.61lb)

AC INDUCTION MOTOR

See “Appendix A - Speed, torque curves” on page 39 for AC Induction equivalent circuit model and torque-speed curve

Specifications	Value
Rated power	120 W
Rated volts	36 VAC
Maximum Speed	4000 RPM
Rated amps	6 Amps
Resistance (L-L)	0.7 Ohms
Inductance (L-L)	2.27 mH
Encoder type	8 pins
Dimensions (HxWxD)	3.7 x 17 x 15cm (4.92”x 6.7” x 6”)
Weight	3.0 Kg (6.61lb)

MOTOR COUPLING BASE

Dimensions (HxWxD)	12.5 x 50 x 16.5cm (1.45”x 19.69” x 6.5”)
Weight	3.5 Kg (7.71lb)

PIN ASSIGNMENTS

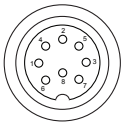
ENCODER PIN ASSIGNMENTS

The BLDC, AC Induction and DC generator motor encoders are quadrature encoders with index (A, B & Z) running 1000 pulses per revolution.

BLDC Encoder

The BLDC motor encoder has one connector with 8 pins:

Pin Number	Pin Description
1	Quadrature A
2	Quadrature B
3	Index Z
4	+5V
5	GND
6	U
7	V
8	W



AC Induction Encoder

The AC Induction motor encoder has one connector with 5 pins:

Pin Number	Description
1	A
2	B
3	Z
4	+5V
5	GND

The AC induction motor encoder has the following characteristic when no load is connected to it:

120Hz = 3600rpm where 120Hz represents the phase current frequency in Hertz and 3600rpm represents the expected speed in revolution per minute when no load is connected. The relation is linear from 0 to 120Hz.

DC Generator Encoder

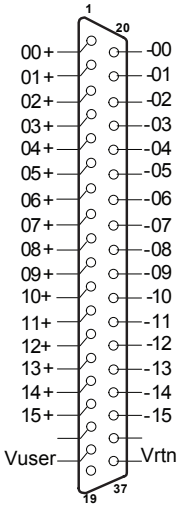
The DC generator has one 5-pin connector:

Pin Number	Pin Description
1	Quadrature A
2	Quadrature B
3	Index Z
4	+5V
5	GND

DB37 AND 50-PIN CONNECTOR PIN ASSIGNMENTS

OP5142EX1 AnalogIn Simulink Block and OP5340

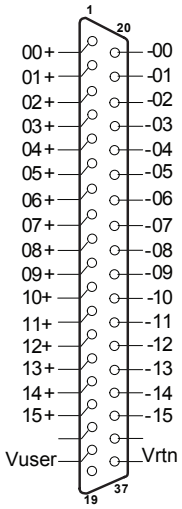
Simulink block library path:
RT-LAB I/O \ Opal-RT \ OP5142 \ OP5142EX1 AnalogIn
RT-LAB I/O \ Opal-RT \ OP5142 \ OpCtrl OP5142EX1, bit. OP5142_1-EX-0000-2_1_b1-DK-02-06.bin

	Pinout				
Description	**Ch**	**Pin # DB37 Connector A ch. 0-15**	**Name**	**Comments**	**Connector Diagram**
OP5142EX1 AnalogIn Parameters Controller Name 'OP5142EX1 Ctrl' DataOut port number 1 Number of channels 5	0	1	+IN00	DC Bus Voltage	
		20	-IN00		
	1	2	+IN01	Current A1	
		21	-IN01		
	2	3	+IN02	Current B1	
		22	-IN02		
	3	4	+IN03	Current A2	
		23	-IN03		
	4	5	+IN04	Current B2	
		24	-IN04		
	5	6	+IN05	Spare	
		25	-IN05		
	6	7	+IN06	Spare	
		26	-IN06		
	7	8	+IN07	Spare	
		27	-IN07		

DB37 AND 40-PIN CONNECTOR PIN ASSIGNMENTS

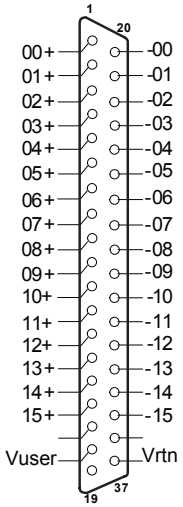
OP5142EX1 Encoder In Simulink Block and OP5353

Simulink block library path:
RT-LAB I/O \ Opal-RT \ OP5142 \ OP5142EX1 Encoder In
RT-LAB I/O \ Opal-RT \ OP5142 \ OpCtrl OP5142EX1, bit. OP5142_1-EX-0000-2_1_b1-DK-02-06.bin

		Pinout			
Description	**Ch**	**Pin # DB37 Connector A ch. 0-15**	**Name**	**Comments**	**Connector Diagram**
OP5142EX1 Encoder In Parameters Controller Name 'OP5142EX1 Ctrl' DataOut port number 2 Number of channels 8	0	1	+DIN00	A+ Motor 1	
		20	-DIN00		
	1	2	+DIN01	B+ Motor 1	
		21	-DIN01		
	2	3	+DIN02	Z+ Motor 1	
		22	-DIN02		
	8	9	+DIN08	A+ Motor 2	
		28	-DIN08		
	9	10	+DIN09	B+ Motor 2	
		29	-DIN09		
	10	11	+DIN10	Z+ Motor 2	
		30	-DIN10		

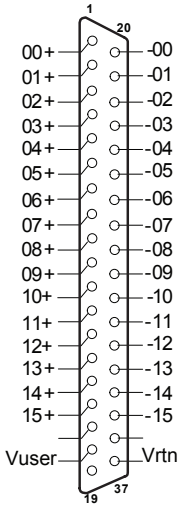
OP5142EX1 Digital In Simulink Block and OP5353

Simulink block library path:
RT-LAB I/O \ Opal-RT \ OP5142 \ OP5142EX1 DigitalIn
RT-LAB I/O \ Opal-RT \ OP5142 \ OpCtrl OP5142EX1, bit. OP5142_1-EX-0000-2_1_b1-DK-02-06.bin

		Pinout			
Description	**Ch**	**Pin # DB37 Connector A ch. 0-15**	**Name**	**Comments**	**Connector Diagram**
OP5142EX1 DigitalIn Parameters	3	4	+DIN03	Fault 1	
Controller Name: 'OP5142EX1 Ctrl'		23	-DIN03		
	4	5	+DIN04	Hall effect-U1	
DataOut port number: 3		24	-DIN04		
	5	6	+DIN05	Hall effect-V1	
Number of channels: 8		25	-DIN05		
	6	7	+DIN06	Hall effect-W1	
		26	-DIN06		
	11	12	+DIN11	Fault 2	
		31	-DIN11		
	12	13	+DIN12	Hall effect-U2	
		32	-DIN12		
	13	14	+DIN13	Hall effect-V2	
		33	-DIN13		
	14	15	+DIN14	Hall effect-W2	
		34	-DIN14		

OP5142EX1 EventGenerator Simulink Block and OP5353

Simulink block library path:
RT-LAB I/O \ Opal-RT \ OP5142 \ OP5142EX1 Encoder In
RT-LAB I/O \ Opal-RT \ OP5142 \ OpCtrl OP5142EX1, bit. OP5142_1-EX-0000-2_1_b1-DK-02-06.bin

		Pinout			
Description	**Ch**	**Pin # DB37 Connector A ch. 0-15**	**Name**	**Comments**	**Connector Diagram**
OP5142EX1 PWM Out Parameters Controller Name 'OP5142EX1 Ctrl' DataIn port number: 1 Number of PWM signals: 6	0	1	+DOUT00	Inverter 1 IGBT1 control signal	
		20	Vrtn 1A		
	1	2	+DOUT01	Inverter 1 IGBT2 control signal	
		21	Vrtn 1A		
	2	3	+DOUT02	Inverter 1 IGBT3 control signal	
		22	Vrtn 1A		
	3	4	+DOUT03	Inverter 2 IGBT1 control signal	
		23	Vrtn 1A		
	4	5	+DOUT04	Inverter 2 IGBT2 control signal	
		24	Vrtn 1A		
	5	6	+DOUT05	Inverter 2 IGBT3 control signal	
		25	Vrtn 1A		
OP5142EX1 DigitalOut Parameters Controller Name 'OP5142EX1 Ctrl' DataIn port number: 1 Number of PWM signals: 6	6	7	+DOUT06	Clear Fault control signal	
		26	Vrtn 1A		

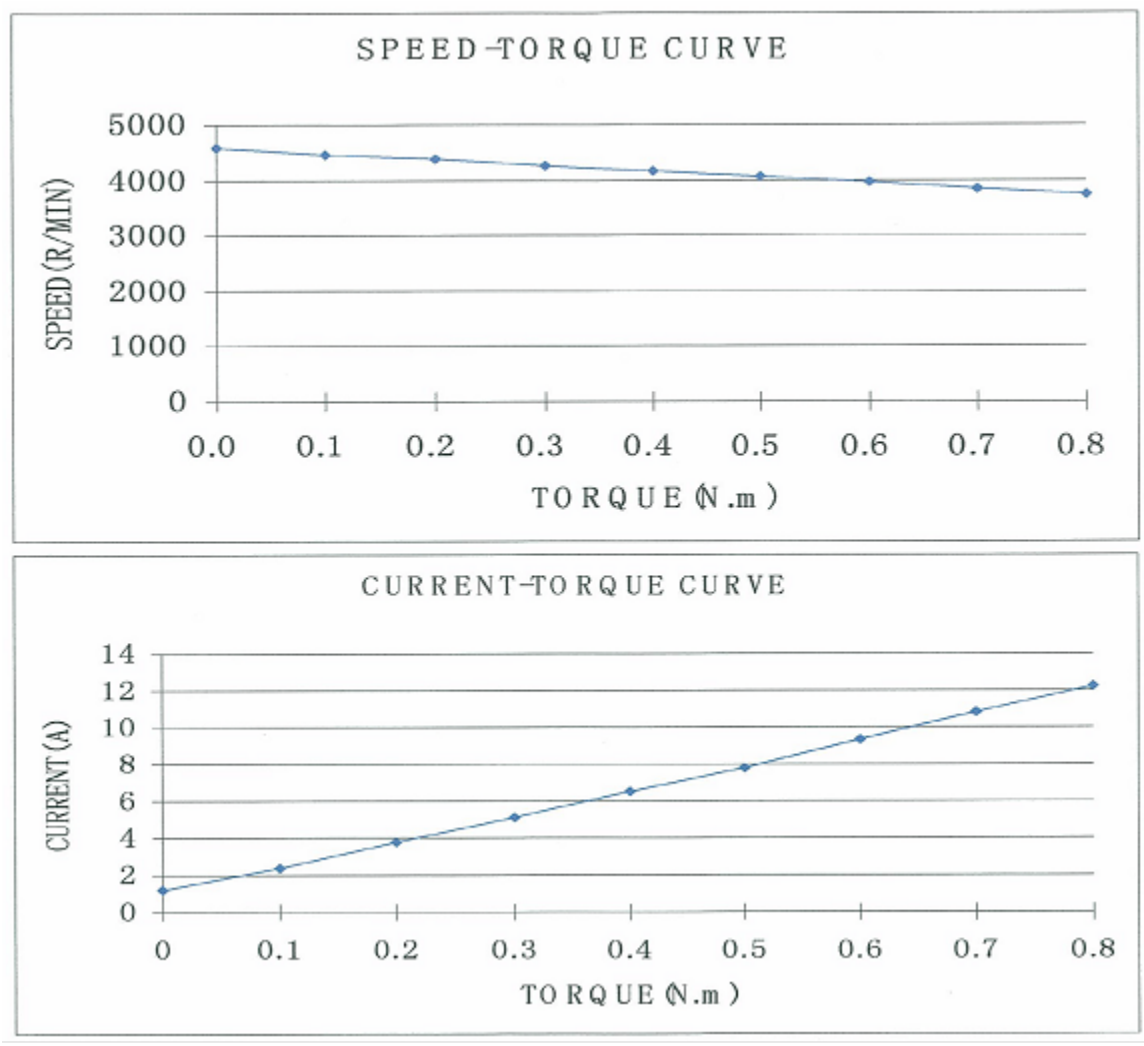
TROUBLESHOOTING

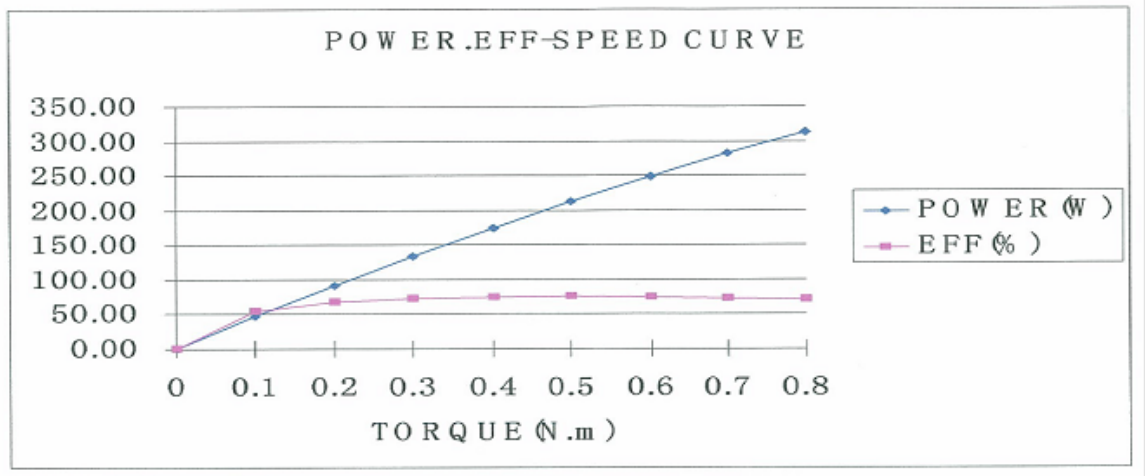
Here are a few troubleshooting hints regarding usual issues that a user may encounter.

Problem	Solution
The motor is running but I have no encoder feedback.	• Make sure the encoder cable is properly connected at both ends (on the motor and on the DriveLab box). • The connector on the DriveLab box side may be hard to push all the way in to the end (for a secure connection with the cable). • Make sure you are monitoring the right encoder. Some tests may require running a motor on inverter circuit 1 but it may have an encoder connection that only fits encoder 2. Therefore, you need to ensure that you are monitoring encoder 2, not encoder 1.
The model is running but the motor does not rotate when attempting to control it from the software.	• Make sure the power connections are secured (+36V from external power supply) and that the external power supply is turned on. • Make sure the DriveLab box is turned on. • Make sure the I/O cables from the real-time simulator are plugged into the DriveLab box. • Make sure the 3-phase (A, B & C) cables are properly plugged from the DriveLab box to the motor and are not inverted (see detail for each motor in this document to make sure your connections are good). • Make sure you are driving the right inverter circuit. You may drive inverter circuit 1 while your motor is connected to inverter circuit 2. • Make sure there is no fault on the inverters. If you are using your own model, try to use the model provided by Opal-RT to run the motor first.
The BLDC motor does not rotate when using the model provided with the kit.	• The BLDC model is the only one that requires feedback from the encoders (U, V and W). If the encoders are unplugged, it will not work. Make sure the encoder cable is properly plugged into the DriveLabKit (loose connections may cause problems).
The fault LEDs on the DriveLab board (internal) are ON as soon as the external power supply is powered on and that a voltage of at least 18V is applied. However, the fault LEDs on the DriveLab kit (external) are OFF.	• This is a common behavior of burned fuses on the DriveLab board. You can check that the fuses F2, F90 and F95 are good. If not, you must replace them. Those fuses are T1.25A250V.
Unable to make faults with the DC motor and DC generator.	• This is related to the fault clearance signal always being active. Look for the models provided by Opal-RT to see how the fault clearance signal is processed. The fault clearance signal must be high (1) at all times, except when a clear fault request occurs (low (0). If the signal is always low (0), the fault is always cleared, therefore faults cannot occur in this condition. • Note that if the DigitalOut block that gives access to fault clearance is not in the Simulink model, the default status of the digital output hardware line is high (1).

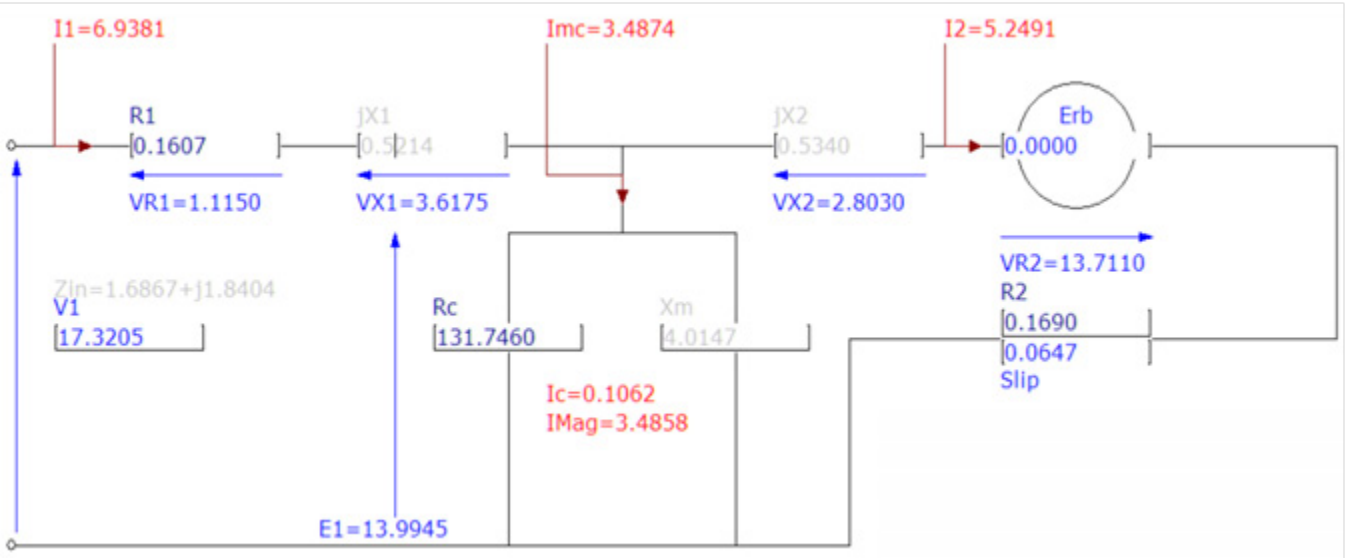
APPENDIX A - SPEED, TORQUE CURVES

DC MOTOR SPEED-TORQUE, CURRENT-TORQUE AND POWER EFFICIENCY-SPEED CURVES





AC INDUCTION EQUIVALENT CIRCUIT MODEL AND TORQUE-SPEED CURVE



APPENDIX B

LIST AND LOCATION OF COMPONENTS ON THE DRIVELAB BOARD

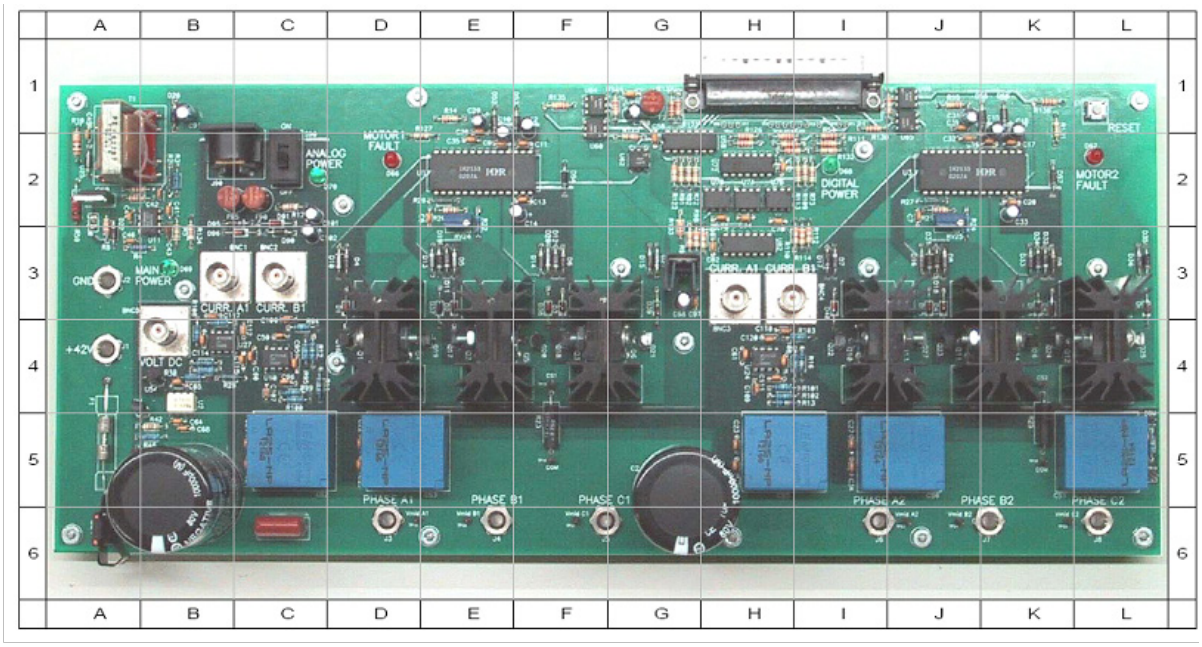


Figure 19: The DriveLab board

Each 3-phase inverter uses MOSFETs as switching devices. The 3-phase outputs for both inverters are identified as A1, B1 and C1 for Inverter 1 and A2, B2 and C2 for Inverter 2 (see Figure 20). The power supply for the 3-phase bridge drivers for the inverters is derived from the DC bus through a flyback converter (A-2). The inverters are driven by 3-phase bridge drivers (IR2133). The PWM inputs are isolated before being fed to the drivers. See the following figure.

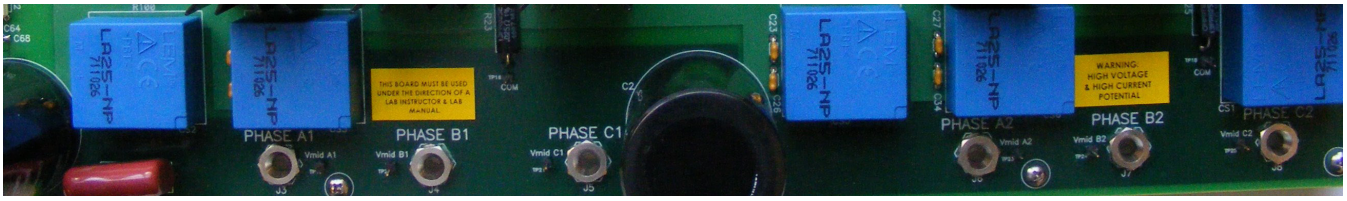


Figure 20: DriveLab board phase connectors

+/-12V signal supply is required for the isolated analog signals (outputs of the DriveLab box). Switch S90 (C-2) controls the signal power to the board. The green LED D70 (C-2) indicates if the supply is available to the board or not. Fuses F90 (C-2) and F95 (B-2) provide protection for the +12V and -12V supplies respectively (see Figure 21).

Figure 21: Analog power LED and fuses

The board has over-current protection for each inverter. An over-current fault on inverter 1 is indicated by the red LED labeled “MOTOR FAULT 1” and an over-current fault on inverter 2 is indicated by the red LED labeled “MOTOR FAULT 2” (see Figure 22).

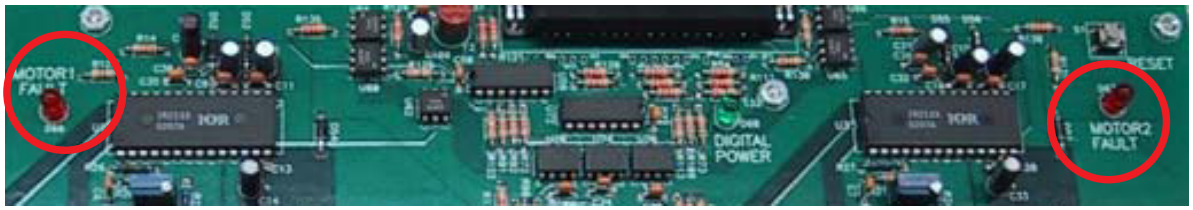


Figure 22: Motor fault LEDs

Probe points are provided to observe the inverter quantities. BNC connector “VOLT DC” (B-4) is provided to probe the DC bus voltage. Note that the scaling factor of the DC bus input voltage is 1/10. See the following figure.

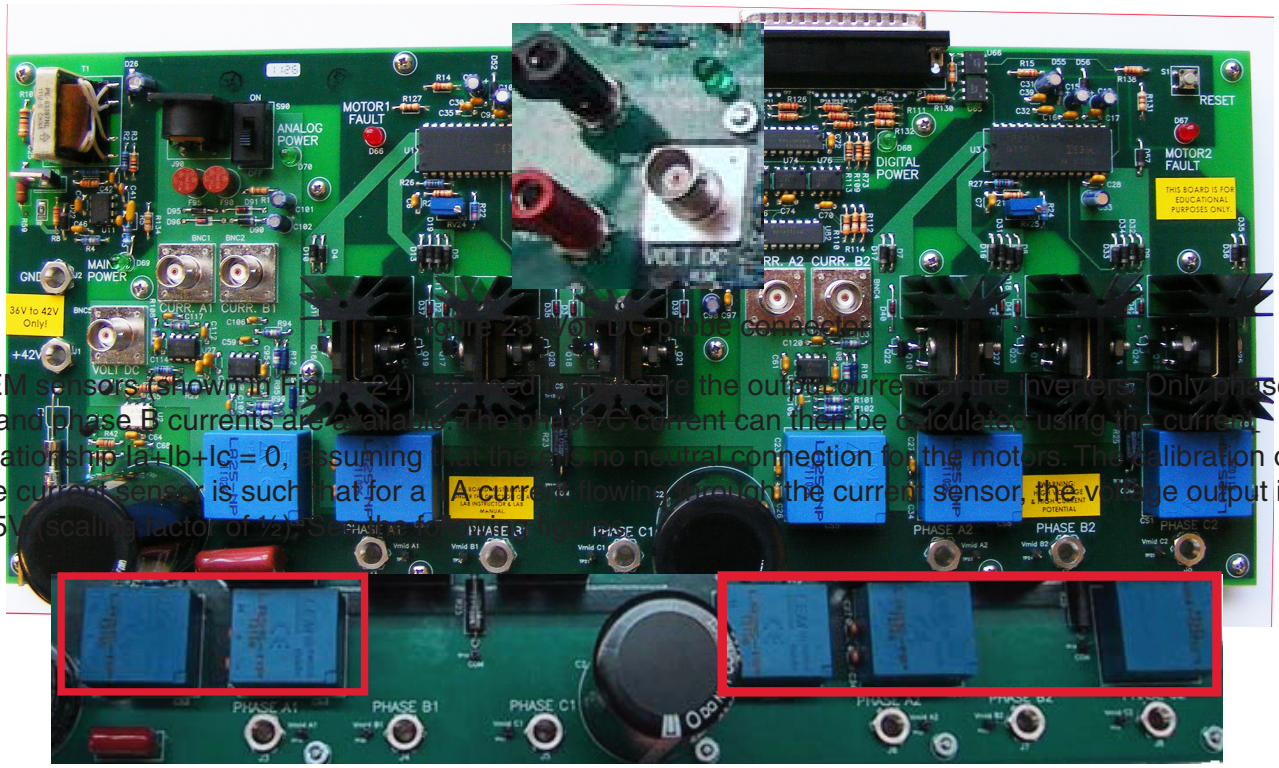


Figure 23: Volt DC probe connector

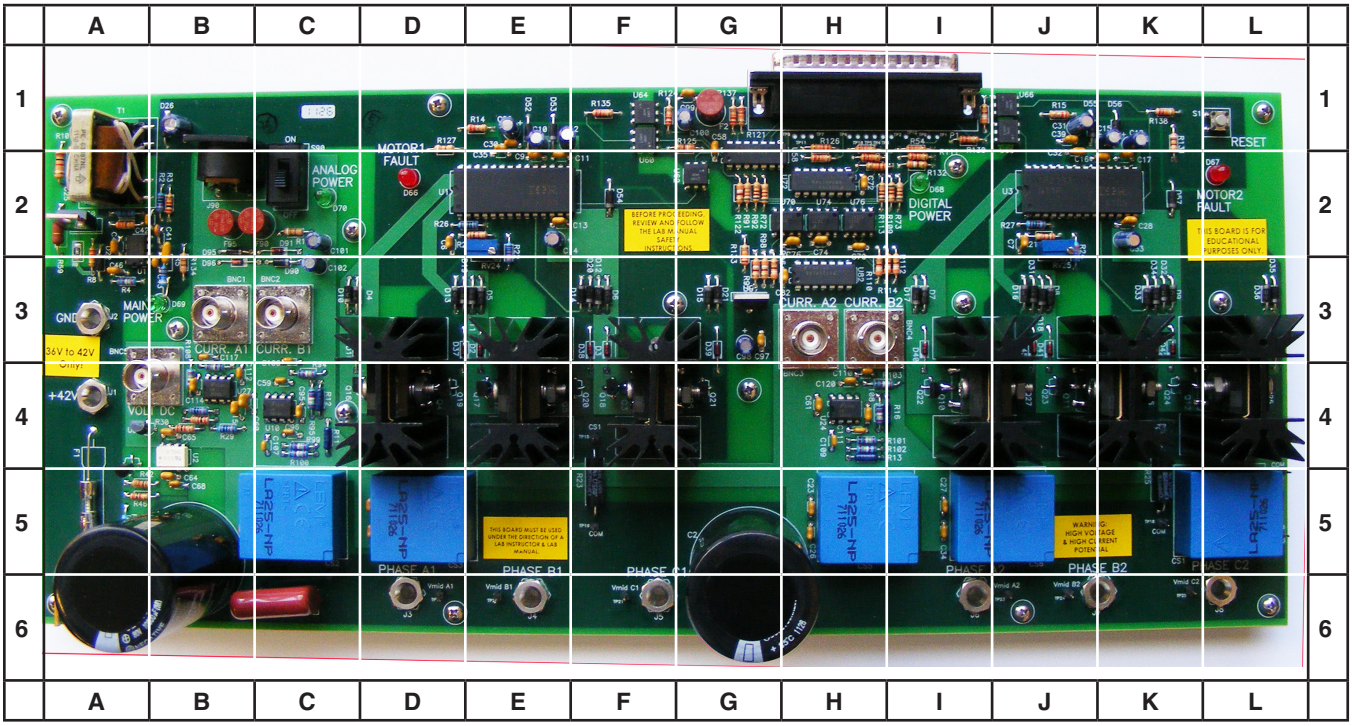
LEM sensors (shown in Figure 24) are used to measure the output current of the inverter. Only phase A and phase B currents are available. The phase C current can then be calculated using the current relationship $I_a+I_b+I_c = 0$, assuming that there is no neutral connection for the motors. The calibration of the current sensor is such that for a 1 A current flowing through the current sensor, the voltage output is 0.5 V (scaling factor of ½). See the following figure.

Figure 24: LEM Sensors

Figure 25: Current probe BNC connectors

See Appendix G for an exhaustive list of the DriveLab board components and their location.

DRIVELAB BOARD CHART



Number	Component	PCB Reference	Chart Location
1	Terminal +36	J1	A-4
2	Terminal GND	J2	A-3
3	Terminal PHASE A1	J3	D-6
4	Terminal PHASE B1	J4	E-6
5	Terminal PHASE C1	J5	G-6
6	Terminal PHASE A2	J6	J-6
7	Terminal PHASE B2	J7	K-6
8	Terminal PHASE C2	J8	L-6
9	DIN connector for ±12 V signal supply	J90	B-2
10	Signal supply switch	S90	C-2
11	Signal supply +12 V fuse	F90	C-2
12	Signal supply -12 V fuse	F95	B-2
13	Signal supply LED	D70	C-2
14	Motor – Fault LED	D66	D-2
15	Motor – Fault LED	D67	L-2
16	Digital power LED	D68	I-2
17	Main power LED	D69	B-3
18	Inverter 1		D-3 to G-4
19	Inverter 1		I-3 to L-4
20	Inverter 1 DC link capacitor	C1	B-5
21	Inverter 2 DC link capacitor	C2	G-5
22	Inverter 1 Driver IC IR2133	U1	E-2
23	Inverter 2 Driver IC IR2133	U3	J-2
24	Digital supply fuse	F2	G-1
25			
26	Reset switch	S1	L-1
27	Phase A1 current sensor (LEM)	CS2	C-5
28	Phase B1 current sensor (LEM)	CS3	D-5
29	Phase A2 current sensor (LEM)	CS5	H-5
30	Phase B2 current sensor (LEM)	CS6	J-5
31	DC link current sensor (LEM)	CS1	L-5
32	Volt DC	BNC5	B-4
33	Curr A1	BNC1	B-3
34	Curr B1	BNC2	C-3
35	Curr A2	BNC3	H-3
36	Curr B2	BNC4	I-3

APPENDIX C

EXTERNAL POWER SUPPLY

The external power supply provides a settable fuse to allow adjustments for specific voltage inputs: 100, 120, 220 or 240 volts. Make sure that the fuse is set to the appropriate setting for your application:

1. Make sure that there is no power to the power supply.
2. Remove the fuse holder from the plug assembly
3. Remove the fuse from the holder and twist to desired adjustment setting
4. Return the fuse to the holder
5. Slide the holder back into the plug assembly.

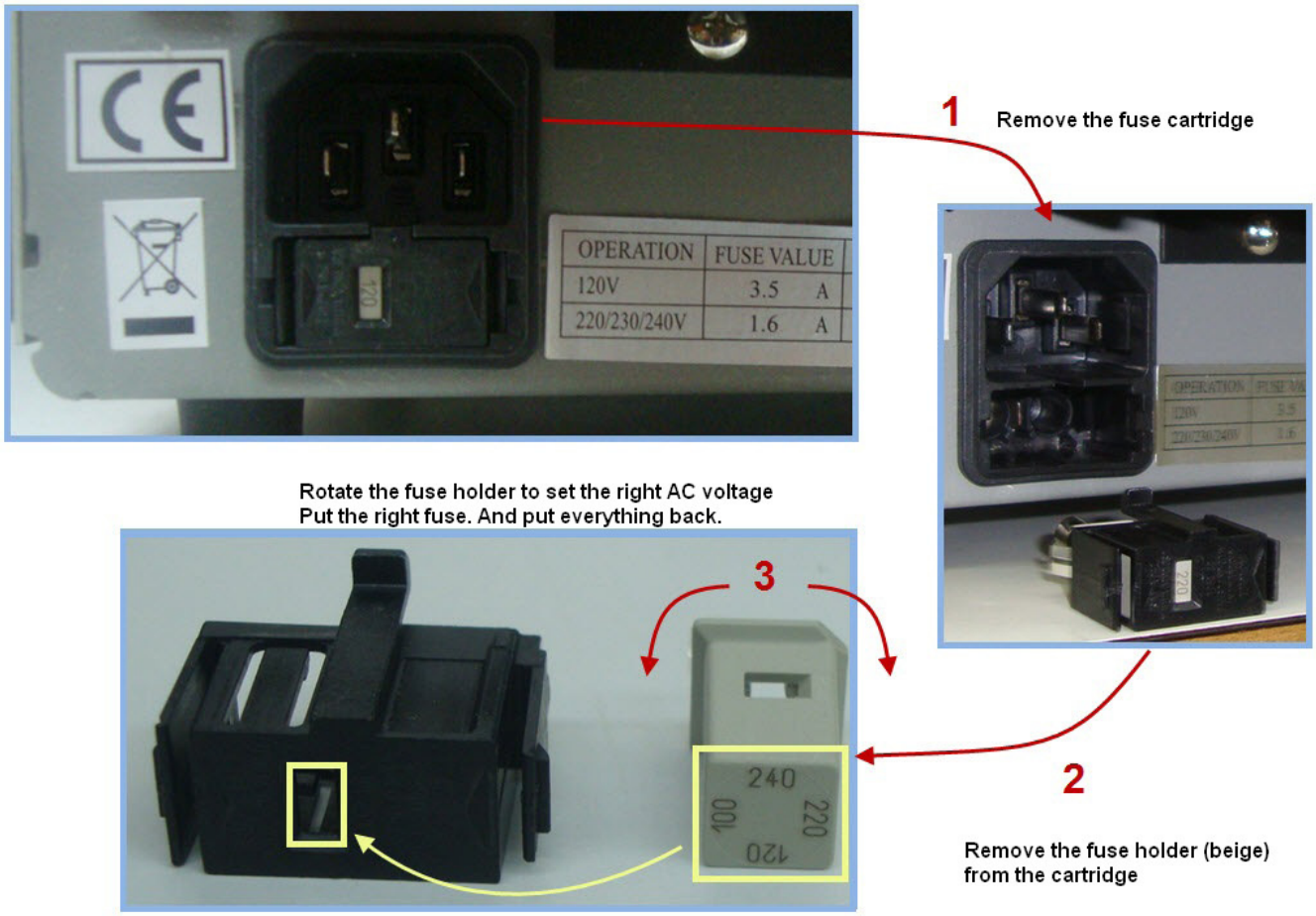


Figure 26: Fuse adjustment instructions

LIMITED WARRANTY

Limited Warranty

Opal-RT Technologies Inc. warrants to the original purchaser and/or ultimate customer (“Purchaser”) of Opal-RT products (“Product”) that if any part thereof proves to be defective in material or workmanship within one (1) year, such defective part will be repaired or replaced, free of charge, at Opal-RT Technologies’ discretion, if shipped prepaid to Opal-RT Technologies Inc. at 1751 Richardson, suite 2525, Montreal, Quebec, Canada, H3K 3G6, in a package equal to or in the original container. The Product will be returned freight prepaid and repaired or replaced if it is determined by Opal-RT Technologies Inc. that the part failed due to defective materials or workmanship. Otherwise, the fees will be charged to the client (see article “Warranty Limitation and Exclusion”). The repair or replacement of any such defective part shall be Opal-RT Technologies’ sole and exclusive responsibility and liability under this limited warranty.

Purchaser must request an RMA number before shipping any Product for repair:

1. Access the Opal-RT website (www.opal-rt.com/support/ return-merchandise-authorization-rma-request), click on support and select Return Merchandise (RMA).
2. Fill out the online form and submit.
3. Opal-RT’s Support department will evalute the return and either issue an RMA number via email
   - If the Product is returned for repair more than 12 months after purchase, the Purchaser is responsible for the cost of repair. Opal-RT will assess the repair and prepare a quote. The RMA number will be sent with the quote.
4. Only when the Purchaser receives the RMA number, may they ship the Product, prepaid, to Opal-RT.

Return Policy

The following fees will apply when customers return products for credit:

A full credit, less a 15% fee and less return fee will only be issued if the product is in perfect working condition and if the product is returned within 1 month following the shipping date. If repairs are required on the returned product, the cost of these repairs will be deducted from the credit to be issued.

No credits will be issued beyond the one month period.

Exclusions

If third party products are part of the Product, Opal-RT will honor the original manufacturer’s warranty.

This limited warranty does not cover consumable items, such as batteries, or items subject to wear or periodic replacement, including lamps, fuses or filter elements.

Warranty Limitation and Exclusion

Opal-RT Technologies will have no further obligation under this limited warranty. All warranty obligations of Opal-RT Technologies are void if the Product has been subject to abuse, misuse, negligence, or accident or if the Purchaser fails to perform any of the duties set forth in this limited warranty or if the Product has not been operated in accordance with instructions, or if the Product serial number has been removed or altered.

Disclaimer of Unstated Warranties

The warranty printed above is the only warranty applicable to this purchase. All other warranties, express or implied, including, but not limited to, the implied warranties of merchantability or fitness for a particular purpose are hereby disclaimed.

Limitation of Liability

It is understood and agreed that Opal-RT Technologies' liability, whether in contract, in tort, under any warranty, in negligence or otherwise shall not exceed the amount of the purchase price paid by the purchaser for the product and under no circumstances shall Opal-RT Technologies be liable for special, indirect, or consequential damages. The price stated for the product is a consideration limiting Opal-RT Technologies' liability. No action, regardless of form, arising out of the transactions under this warranty may be brought by the purchaser more than one year after the cause of actions has occurred.

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